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PHYSIOLOGY AND PATHOLOGY OF THE DIGESTION OF FAT IN INFANCY

THEIR APPLICATION TO INFANT-FEEDING *

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The food of infants comes in the main from two sources, human milk and cows' milk, the former being the natural food and the latter the best substitute we have when the former supply fails us. A brief description of these two milks is necessary for a clear conception of the subject.

The percentage of fat in cows' milk varies with the individual cow and the species. The milk of the ordinary grade cow, the Holstein or Ayrshire, contains 4 per cent. or less of fat, and that of the Jersey or Guernsey 4 per cent., or more, of fat. The fat is held in a coarser emulsion and separates more easily than that of human milk. There are other differences in the chemical and physical composition of the two milk-fats, but these will not be taken up in this paper.

Human milk normally contains, in round numbers, about 4 per cent. of fat; this percentage, however, may vary considerably in pathologic conditions, the extremes being 0.1 per cent.[1] and 13.7 per cent.[2] Every woman has a certain amount of fat to secrete in her milk, and, under like conditions, gives the same total day by day. The percentage of fat in the milk gradually increases in a certain definite curve from the beginning to the end of each nursing, the smallest percentages coming at the beginning and the highest at the end.[2] For example, the first part of the milk usually contains 2 per cent. of fat, and the last part 6 per cent. of fat; and the mixture of the whole amount of milk secreted in a single breast contains 4 per cent. of fat. The amount of milk secreted does not influence this curve otherwise than by making the ascent rapid or

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1. Moll: Ueber Fettvermehrung der Frauenmilch durch Fettzufuhr, nebst einem Beitrag für die Bedeutung der quantitativen Fettunterschiede für das Gedeihen der Brustkinder, Arch. f. Kinderh., xlviii, 161.

2. Forrest, M.: Ueber die Schwankungen im Fettgehalte der Frauenmilch und die Methodik der Milchentnahme zu Fettbestimmung, Arch. f. Kinderh., xlii, 1.

3. Engel: Ueber die quellen des Milch und Colostralfettes und über die bei der Milchsekretion wirkenden Kräfte, Arch. f. Kinderh., xliii, 194 and 204.

gradual.[4] Occasionally there is more fat in the first part of the milk than in the last part and the curve is just the reverse of the one just described.[5]

It is probable that the body-fat as well as the food-fat may be the source of milk-fat,[6] but it is not clear how the fat can be obtained from this source. Thiemich examined the literature on the influence of food on the quantity of fat secreted in the milk and came to the conclusion that a fat-free diet not only changed the quality of the fat, but also caused at the same time a diminution in the amount of fat in the milk. When a person is underfed, an increase in the fat in the food results in an increase in the fat in the milk,[7] but when large amounts of fat are added to a normal diet there is only a temporary increase in the amount of fat in the milk despite the excess of fat in the diet.[8] Ebstein[9] found in his clinic that many women with a fat-poor breast-milk would secrete more fat if they were given more fat in the food.

The amount of fat ingested by infants naturally depends on the amount in the milk, the amount of milk taken, and the part of the milk given. In asylums where one wet-nurse feeds two or more babies, the baby nursed first gets a milk relatively low in fat and the last one a milk relatively high in fat (possibly 6 per cent.). This fact is of great practical importance in feeding very delicate or sick babies, which are unable to digest large amounts of fat of any sort. Such babies may be given the first part of the milk which comes from the breast, or if desired skimmed drawn breast-milk. The wet-nurse is always instructed to nurse the sick baby first, and her own baby last; one of the reasons is that the sick baby does better on the weaker milk. In general, the amount of milk which

4. Aurnhammer: Ueber die Beziehungen zwischen Milch production und Fettgehalt der Milch, Arch. f. Kinderh., 1909, li, 160.

5. Engel: Zur Methodik der Fettbestimmung in der Frauenmilch und die Methodik der Milchentnahme zu Fettbestimmungen, Arch. f. Kinderh., 1906, xliii, 181.

6. Bendix: Ueber den Uebergang von Nahrungsfetten in die Frauenmilch, Deutsch. med. Wchnschr., 1888, No. 14; Thiemich: Ueber den Einfluss der Ernährung und Lebensweise auf die Zusammensetzung der Frauenmilch, Monatschr. f. Geburtsch. u. Gynäk., 1899, ix, No. 4; Gogitidse: Vom Uebergang des Nahrungsfettes in die Milch, Ztschr. f. Biol., xlv, 353; ibid., xlv, 403; Caspari: Ein Beitrag zur Frage nach der quelle des Milchfettes, Arch. f. Anat. u. Physiol. (Suppl.), 1899, 267; Engel: Ueber das Milchfett Stillender Frauen bei der Ernährung mit spezifischen Fetten, Wien. klin. Wchnschr., 1906, No. 29, p. 898.

7. Johannessen: Studien zur Sekretionsphysiologie der Frauenmilch, Jahrb. f. Kinderh., xxxix, 380.

8. Albert, F.: Ueber den Einfluss von Fettfütterung auf die Milchmenge und den Fettgehalt der Milch, Ref. Malys Jahresbr. f. Tierchemie, xxix, 253; Henriques and Hansen: Untersuchungen über die Fettbildung im Tierorganismus nach intensiver Fettfütterung, Malys Jahresbr. f. Tierchemie, xxix, 68.

9. Ebstein: Die Verdauungsstörungen im Säuglingsalter, Ebstein-Schwalbes Handb. d. prakt. Med., 1900, ii, 299.

a baby will take decreases, the richer it is in fat.[10] This, however, does not usually hold true of sick babies, because the amount of milk they take in twenty-four hours does not increase with the lowered percentage of fat, but only with the return to health.[1] Therefore, when a baby has an acute infection, such as pneumonia, the milk mixture should be diluted as a whole; the fat should not be removed entirely from the mixture, because it has twice as much food value as either the sugar or protein, and because in such cases the presence or absence of fat does not influence the amount of milk taken. If, on the other hand, a healthy infant is given 5 per cent. or more of fat in its food, it will usually take less and less, and if the amount of fat is diminished it will eat more. Many babies get 6, 10 and even 12 per cent. of fat in the food because the milk mixtures are prescribed ignorantly or made improperly. This could be avoided by estimating the amount of fat in the milk by the Babcock method. When normal babies are upset by fat, it is the rule rather than the exception to find that they are receiving more than 5 per cent. in the food.

PHYSIOLOGY

The physiology of the digestion of fat is not simple, but certain facts have been established which throw some light on what is happening to the fat in the gastro-intestinal canal.

STOMACH DIGESTION

The motility of the stomach is influenced by many things, such as the concentration and the character of the food.[11] Nothing has so much influence on the time required to empty the stomach as variations in the amounts of fat, which delay or hasten the evacuation of food into the duodenum. When there is a large amount of fat in the food, the food is kept in the stomach longer, and when a small amount, a shorter time.[12] According to some writers,[13] the stagnation of fat has a connection with the pathologic condition of pyloric stenosis. It has been demonstrated in animals that fat delays the secretion of hydrochloric acid. Cannon has shown that the cardiac orifice remains open as long as the reaction of the cardia is alkaline; as soon as the reaction becomes acid, the cardiac orifice closes and remains so until the neighboring food components become alkaline. The pyloric valve acts in a manner directly

10. Gregor: Der Fettgehalt der Frauenmilch und die Bedeutung der physiologischen Schwankungen desselben in bezug auf das gedeihen der Kinder, Samml. klin. Vort. von Volkmann, 1901, No. 302.

11. Clark: Am. Jour. Med. Sc., May and June, 1909.

12. Tobler and Bogen: Ueber die Dauer der Magenverdauung der Milch und ihre Beeinflussung durch verschiedene Factoren, Monatschr. f. Kinderh., vii, 12.

13. Tobler: Beobachtungen über die Zusammensetzung des Mageninhalts bei kongenitaler Pylorusstenose, Verhandl. d. Gesellsch. f. Kinderh., 1907, p. 411.

opposed to that at the cardia. When the material in the antrum pylori is acid, the valve opens and *vice versa.*[14]

These two facts may be applied clinically in explaining regurgitation due to too much fat in the food. Fat delays or inhibits the secretion of hydrochloric acid, and the cardiac sphincter, or lid to the stomach, remains open so that milk can be pushed back into the esophagus by the peristaltic movements of the stomach. If the amount of fat in the food is diminished, regurgitation stops, presumably because the normal amount of hydrochloric acid is again secreted, causing the entrance to the stomach to close and the outlet to open at the proper time.

It has been assumed until recently that only the pancreatic juices contain fat splitting ferments. Sedgewick[15] found a ferment in the stomach contents of infants which is capable of splitting in the test-tube one-fourth of the fat, and in the body about 12 per cent. of the fat ingested. Ibrahim[16] found this same ferment in the mucous membrane of the stomach of both the fetus and the new-born baby, and proved conclusively that there is a very powerful fat-splitting ferment which in a 9-months old baby that had died from pneumonia split in twenty-four hours over 40 per cent. of the fat in the yolk of an egg.

Nature, however, provides that too much fat shall not be set free in the stomach at one time. This is brought about in the following manner: When the casein of milk is coagulated in the stomach, practically all the fat is entangled in its meshes. The casein surrounding it must be digested before any more fat can be reached by the digestive juices, and thus only as much fat is set free as the progress of digestion warrants.

INTESTINAL DIGESTION

When the stomach digestion is complete, the food is discharged into the duodenum accompanied by organic or inorganic acids which start the secretion of the pancreatic juice and bile.[17] Ibrahim[18] substantiated Zweifel's[19] findings that the pancreas of the fetus contains a fat-splitting ferment and that the action of this ferment is increased materially by the

14. Cannon: Am. Jour. Physiol., 1908, xxiii, 105.

15: Sedgewick: Die Fettspaltung im Magen des Säuglings, Jahrb. f. Kinderh., 1906, lxiv, 194.

16. Ibrahim, J., and Kopec, T.: Die Magenlipase beim menschlichen Neugeborenen und Embryo, Ztschr. f. Biol., München., 1909, liii, 201.

17. Baylies and Starling: Jour. Physiol., 1902, xxviii, 325; 1903, p. 174.
Laqueux: Sur la présence et la localisation de la sécrétine dans l'intestin du nouveau-né et du fœtus humain, Compt. rend. Soc. de biol., 1896, lxi, 33.
Ibrahim and Gross: Zur Verdauungsphysiologie des Neugeborenen, Ref. in Deutsch. med. Wchnschr., 1908, No. 25, p. 1128.

18. Ibrahim: Neuere Forschungen über die Verdauungsphysiologie des Säuglingsalters. Verhandl. d. Gesellsch. f. Kinderh., 1908, p. 25.

19. Quoted by Ibrahim (see note 18).

addition of bile,[20] just as it is in the adult. Ibrahim was unable to find any fat-splitting ferment in the mucous membrane of the small intestine or large intestine.

ABSORPTION

There is considerable evidence that neutral fat (unsplit fat) is not absorbed as such into the intestinal wall: for example, hydrous wool fat and paraffin, which may be made into emulsions and cannot be split, are not absorbed.[21] It has also been shown by animal experimentation that the amount of fat in the chyme is directly proportional to the amount of fat split.[22] It is also taught by some that fat is absorbed both in the form of an emulsion and in the form of water-soluble soaps, neither view excluding the other. This latter view has been strengthened by the investigations of Kastle and Loevenhart[23] who demonstrated the almost universal presence of lipase in the tissues, and showed that this ferment could reverse its action. That is to say, it can synthesize or change soaps back into neutral fats as well as split neutral fats and form soaps. It is, therefore, possible that the soaps, which have been formed during digestion, may be changed during their passage through the intestinal epithelium by the reversible action of lipase back into neutral fat, because one finds neutral fat almost exclusively in the lymph-stream. Whitehead's[24] experiments on cats seem to strengthen this statement, because he found that butter-fat stained with Sudan III lost the stain during absorption (soaps will not stain with Sudan III); Sudan-staining fat was seen in the lumen of the intestine; none was seen in the intestinal epithelium and a Sudan-staining fat was again found in the lacteals of the villi.

A large part of the fat absorbed goes through the portal veins to the liver,[25] and the rest of it is carried by the lymphatics through the thoracic duct to the blood-stream, where it may be demonstrated by the ultra-microscope. It is called digestion lipemia and commences two to three hours after meals and disappears after seven to eight hours.[26] The

20. Uffenheimer: Physiologie des Magendarmkanals beim Säugling, Ergebn. d. inn. Med. u. Kinderh. 1908, No. 2, 321.

21. Connstein, W.: Arch. f. Anat. u. Physiol., 1899, p. 30; Henriques and Hansen: Zentralbl. f. Physiol., 1900, xiv, 313.

22. Levites: Ueber die Verdauung der Fette im tierischen Organismus, Ztschr. f. physiol. Chem., xlix, 273; liii, 349.

23. Kastle and Loevenhart: Am. Chem. Jour., 1900, xxiv, 491.

24. Whitehead, R. H.: A Note on the Absorption of Fat, Am. Jour. Physiol., 1909, xxiv, 294.

25. Weinland: Physiologie der Leber, Nagel's Handb. d. Physiol., ii, Part 2, 456.

26. Ueber ultramikroskopische Blutuntersuchungen zur Zeit der Fettresorption bei Gesunden und Kranken, Wien. klin. Wchnschr., 1907, p. 851; Schelble: Untersuchungen über die Fettresorption des Säuglings, München. med. Wchnschr., 1908, No. 10; Bahrdt: Demonstration zur Untersuchung der Lipämie beim Säugling, Breslauer Tagung der Freien Vereinigung für wissenschaftliche Pädiatrie, 1908, Monatschr. f. Kinderh., vii, 107.

height of the curve is dependent on the amount of fat in the food, and the age and condition of the infant.

The absorption of fat is extraordinarily good in health in babies fed on cow's milk as well as in those fed on human milk; it is usually over 90 per cent. and may be as high as 98 per cent. of the fat ingested.[27] Eight per cent. to 11 per cent. of the ingested fat is absorbed in the upper part of the small intestine[22] and the absorption of fat is nearly complete at the ileocecal valve.[22] The large intestine is capable of absorbing fat in large amounts under special favorable conditions[28] but under ordinary circumstances absorption here is probably very little.

Estimation of the amount of fat in the stools of babies in starvation and in health makes it probable that the greater part of the fecal fat comes from the food and not from the intestinal secretions.[27] It is evident, therefore, that microscopic fat that is found in the stools gives us valuable information about the digestion. It is necessary first to know how much fat may normally be found in a stool. There is a comparatively large amount of fat present in the first days of life, and this amount gradually becomes less[29] as the babies grow older, decreasing from 50 per cent. of the dried stools to between 14 and 25 per cent. There is so much fat passed in the stools during the early weeks that it is practically impossible to ascertain by simple microscopic examination whether there is an excess or not. In later infancy less fat is present and therefore, microscopic examinations are of more value. In normal and in many pathologic conditions the greater part of the fat, 75 per cent. or more, is split by the digestive juices and bacteria into fatty acids and soaps.

A recapitulation of the facts given above is in brief as follows: most of the fat in cows' milk or human milk is in the form of neutral fat; in normal digestion this is partially split in the stomach by the gastric lipase. When the food is emptied into the duodenum, the remainder of the fat is presumably split by the pancreatic juice and saponified by the alkalies surrounding it. This digested fat is absorbed in the small intestine between the duodenum and the ileocecal valve and only the overflow fat goes into the large intestine with the intestinal secretions and bacteria. There the fecal remains are desiccated and eventually evacuated. The normal appearance of stools varies according to the food which the infant

27. Czerny-Keller: Der Kinder Ernährung, Ernährungsstörungen und Ernährungstherapie, Leipzig u. Wien, 1906, p. 263; Freund: Physiologie und Pathologie des Fettstoffwechsels im Kindesalter, Ergebn. d. inn. Med. u. Kinderh., 1909, ii, 139.

28. Hamburger, H. J.: Ueber die Resorption von Fette und Seife im Dickdarm, Engelmann's Arch., 1900, 433.

29. Talbot, F. B.: The Composition of Small Curds in Infants' Stools, Boston Med. and Surg. Jour., Jan. 7, 1909.

is taking. An excellent description of these stools may be found in a paper by Morse.[30]

STOOLS: MICROSCOPIC EXAMINATION

Much valuable information concerning the digestion of the various food components may be obtained from careful gross and microscopic examinations of the stools. This evidence is definite and accurate and is not misleading like the symptoms obtained from mothers and nurses. There are several quick methods of estimating the fat in the stool under the microscope.

1. The first consists in staining a bit of stool with saturated alcoholic solution of Sudan III. Neutral fat drops stain red. Fatty acids may be in the form of drops or crystals; the former always stain and the latter sometimes stain. Soap splinters and crystals never stain. The total fat in the slide may be estimated by adding a drop of glacial acetic acid to the already stained preparation, and warming it gently until it begins to bubble. This changes soaps into fatty acids which are red drops as long as they remain hot and often when they become cold. The error in this method comes from the fact that it is impossible to differentiate neutral fat and fatty acid drops. I have used this stain nearly three years.

2. The second method consists[31] in staining a scrap of stool with carbol-fuchsin and examining under the microscope. With this, neutral fat remains unstained, fatty acids stain a brilliant red and soaps a dull rose-red. Recently, I have used both stains, one on each of two cover-glass preparations, and thus obtained an estimate of the total amount of fat present, and the relative amounts of neutral fat, fatty acids, and soaps. Preparations from several parts of each stool should be examined in this way because the picture is apt to vary in stools which are not uniform.

The following terms are based on innumerable microscopic examinations of stools many of which were controlled by quantitative chemical analyses:

1. *Entire Digestion of Fat.*—Microscope, No. 7 objective, No. 3 eyepiece. Stain. alcoholic Sudan III. No fat in freshly stained specimen. One to three drops in field after acetic acid and heat.

2. *Normal Digestion.*—No fat or five to eight neutral fat-drops in the entire cover-glass in freshly stained specimen. Five to eight drops in a field after addition of acetic acid and heat. No change in amount of fecal residue.

3. *Slight Excess of Fat.*—No fat or two to four neutral fat-drops in a field. Eight to a dozen drops in a field after acetic acid and heat. No change in amount of fecal matter.

4. *Moderate Excess of Fat.*—No fat or six to eight neutral fat-drops in a field. More than twelve large drops after addition of acetic acid and heat. Considerable fecal material remains unchanged.

30. Morse, J. L.: The Stools in Infancy, New Orleans Med. and Surg. Jour., August, 1910.

31. Jacobson: Sur une réaction colorante des acides gras, Presse méd., 1906, No. 19, p. 147.

5. *Large Excess of Fat.*—No fat, or many fat-drops in a field. Practically the whole slide turns into fat-drops after acetic acid and heat, leaving very little fecal matter unchanged.

If there are any fat-drops in the original preparation it should always be stained with carbol-fuchsin to differentiate neutral fat from fatty acids. The entire cover-glass should be examined and it is usually better to examine preparations from several parts of the stool.

The following deductions can be drawn from these findings:

1. *Entire Digestion of Fat.*—It is always safe to increase the amount of fat in the food if so desired.

2. *Normal Digestion.*—It is usually safe to give more fat if necessary.

3. *Slight Excess of Fat.*—It is difficult to say how much significance should be attached to this. Probably very little.

4. *Moderate Excess of Fat.*—Without symptoms of indigestion it warns the observer to watch the fat more carefully. Yet, curiously enough, the percentage of fat may be increased without causing symptoms of indigestion and subsequently the stool may show "normal digestion." In case there are symptoms of indigestion, however, the microscope confirms our suspicions, and indicates the cause of the symptoms.

5. *Large Excess of Fat.*—This always means too much fat in the food and even if there are no symptoms, it is safer to decrease the amount of fat and examine the stool again. Usually there are symptoms of indigestion with this microscopic picture.

Fat is usually found in a normal stool in some form or other. Neutral fat appears as drops of different size and shape and sometimes as irregular flakes. When there is a very large amount it may be seen with the naked eye; it may be colorless, yellowish or slightly bile stained.

Free fatty acids may be indistinguishable from neutral fat drops except by staining with carbol-fuchsin. Neutral fat drops do not stain, while fatty acids stain; the more intense red the more acid they contain. When they are in the form of crystals, gentle warming will cause them to become drops, which recrystallize on cooling. Soaps may be amorphous or in the form of crystals. They are less shiny than fatty acids and may be stained yellow with bile coloring matter. The bushel-stained soap crystals may be in clumps and are shorter and thicker than fatty acids.

The microscopic examination of the stools of babies only occasionally gives information that the gross examination does not give, but it is a valuable control to inspection. In a few instances, the information is very surprising. It is important to bear in mind that even with considerable microscopic fat, a baby can remain perfectly happy, continue to gain and have no symptoms. This information, therefore, should be taken with reserve. In childhood, when foods other than milk are taken, small amounts of microscopic fat are of more significance. During the third year there should be only a few fat-drops on the whole slide in a normal digestion. More means a disturbance in the digestion of fat.

The closer a child comes to the adult type of diet, the more significance can be attached to information given by the microscope.

MACROSCOPIC EXAMINATION

The gross examination of the stool is the more important because it gives the most valuable information. The commonest abnormal constituents in a stool are soft, fatty curds. Soft curds are either flat white flakes (which look like undigested milk particles) or pin-head elevations; both may be present in the same stool and they are always associated with more or less mucus, which is stained green or yellow. About 60 per cent. of their dried substance is fat. These curds are usually present at one time or other in the stools of all nursing babies and are of no significance even with slight symptoms of indigestion. They are more important in the stools of bottle-fed babies. If there are no symptoms of indigestion and the baby is gaining and happy, the percentage of fat should not be changed, but the significance of these curds should be remembered. If there are symptoms of indigestion, loss of weight, and soft, fatty curds in the stools, there is too much fat in the food. When it is diminished, the curds disappear, the baby becomes happy and gains weight.[32]

These curds should not be confused with tough casein curds, which are white or bile-stained, bean-like masses of varying size and shape. They may be easily differentiated from the fat curd by their physical characteristics. The latter will smooth out on a napkin while the former will not; casein hardens in liquor formaldehydi (formalin) while fat does not. I recently proved [32] by the precipitin reaction that the protein in these curds is cow-casein. They contain varying amounts of neutral fat which is entangled in the meshes of the casein when it coagulates in the stomach. This fat has not been acted on by the digestive juices because it is protected by a coating of casein. It is present in larger or smaller amounts, according to the percentage of fat in the milk and may, therefore, be considered accidental.[33]

Soap stools are very light yellow or white, usually smooth, sometimes salve-like, at other times dry and brittle. The shiny appearance of the fresh surface suggests fat. They are composed almost entirely of soap. Fifty per cent. to 70 per cent. of their dried substance may be fat. They often occur in constipation due to too much fat in the food and disappear when the fat is replaced by other food components. They may be the precursors of a fat diarrhea and if their full significance is not appreciated, they may eventually become part of the clinical picture of infantile atrophy.

32. Talbot, F. B.: Casein Curds in Infants' Stools. Biological Proof of Their Casein Origin, Arch. Pediat., June, 1910.

33. Talbot: The Composition of Large Curds in Infants' Stools, Boston Med. and Surg. Jour., June 11, 1908.

Fat stools are very bright yellow (like Indian meal), oily and soft. They are composed of large amounts of fats, a good proportion of which is in the form of neutral fat or fatty acid. When one of these stools is placed on paper and then removed, there remains behind a grease-spot which will not absorb water (oiled paper). They are usually accompanied by very severe symptoms. Fat should be removed entirely from the milk for a time and very frequently these babies cannot be saved without human milk.

METABOLISM

Most of the figures offered us by metabolism experiments are obtained by the Rosenfeld method of extracting fat, and very recently by the Kumagawa and Suto method. These and other modern methods of fat extraction have been given in more or less detail in the appendix of this paper. Despite the fact that the figures so obtained may not be absolutely correct, I believe that they are of great relative value and help to clear up many of the cases of perverted digestion. While they do not say the final word on the subject, they lead to a more intelligent grasp of the pathology of digestion. This paper does not pretend to consider the rôle of the intestinal flora in normal and abnormal digestion, but I believe that they are of great significance in certain conditions and that they will be found to influence metabolism. For example, Kendall[34] has shown that two factors are necessary for fermentation: a carbohydrate food, and fermentative bacteria; in like manner putrefaction cannot take place without protein plus putrefactive bacteria. Fermentative bacteria cannot act on protein, and putrefactive bacteria cannot act on carbohydrate. It is very difficult, therefore, to draw any conclusions in a subject which is complicated by so many factors. The problems of digestion depend on the balance of all the factors concerned and when the normal balance is upset by any one or many factors, we have a pathologic condition.

The significance of fatty acids and soaps is as yet unknown; probably they are of very little significance in the questions of absorption. Freund (quoted above) has shown that an acid dyspeptic stool can be changed in many instances to a formed "soap stool" by a relative increase in the amount of casein, while an alkaline soap stool can be changed into an acid stool by a relative increase in the amount of carbohydrates. Coincident with the change from an acid to an alkaline stool (according to Kendall) there is a change of the intestinal flora; the acid-forming bacteria which previously predominated are replaced by the putrefactive group of bacteria. When an alkaline stool is made acid the reverse takes

34. Kendall: Boston Med. and Surg. Jour., 1911, clxiv (to appear in March). Read before Suffolk District Medical Society.

place. Bahrdt[35] has recently shown that babies passing "soap stools" have diminished powers of absorption and that they lose more fat than was formerly taught. He found the absorption of fat (Kumagawa and Suto method) as follows:

Name of Baby.	Age, Months.	Weight, Gm.	Fat absorbed. Per cent.	Character of Stools.
Schröder, 7 days	9	7470	82.4	Soap stools
Schüler, 7 days	2	3945	83.2	Mostly soap stools
Weiss, Ia, 5 days....	9/10	3750	81.9	Soap stool
Weiss, Ib	9/10	3750	86.0	Soap stool
Weiss II, 8 days.....	10	3900	93.0	Normal stools

Breast and skim milk.

The fat absorption in these babies with soap stools is, therefore, considerably less than that of normal infants. There is, however, not such a loss of fat as in diarrhea. There is a loss of magnesium and calcium[36] in these soap stools and there is no loss of sodium and potassium. If the stools become acid and change into soft fatty curds there is no longer a loss of calcium and magnesium, but there is a loss of sodium and potassium. With this change comes an increased loss of fat from the body.[36] If this condition becomes more pronounced with diarrhea, there is a considerable loss of fat with the alkalies; the baby loses weight and takes on the appearance of "infantile atrophy."[37] Such babies can only be saved by human milk.[38]

Biedert[39] and Demme[40] designated severe chronic disturbances of digestion in which the stools contained very large amounts of fat as "fat diarrhea." The latter had one such case which came to autopsy and was found to have disease of the pancreas. Hecht[41] and Reuss[42] have reported cases of congenital obliteration of the bile-duct with normal pancreas, in which only one-half of the fat was split. I examined the stools

35. Bahrdt, H.: Untersuchungen über das Symptom der Seifenbildung und die Ausscheidung der Basen im Darm des Säuglings, Jahrb. f. Kinderh., 1910, lxxi, 249.

36. Meyer, L. F.: Jahrb. f. Kinderh., April, 1910, p. 379.

37. Finkelstein: Ueber Alimentäre Intoxikation III, Jahrb. f. Kinderh., 1908, lxviii, 521 and 692.

38. Finkelstein's so-called alimentary intoxication will not be considered in this paper because I believe that the majority of cases which clinically come under this category are not diseases of metabolism, but are bacterial infections of the gastro-intestinal canal, and that the physiologic powers of digestion are so lowered by the disease that the various food components are not digested.

39. Biedert: Jahrb. f. Kinderh., 1879, xiv, 336; ibid. 1888, xxviii, p. 21.

40. Demme: Jahrb. über die Tätigkeit des Jennerschen Kinderspitals in Berlin, 1874 and 1877; quoted from Hecht, Die Faeces des Säuglings, etc., p. 128.

41. Hecht: Die Faeces des Säuglings und Kindes, Berlin-Wien, 1910, p. 128.

42. Reuss: Case of Obliterated Bile Duct (congenital) Reported in Discussion, Jahrb. f. Kinderh., December, 1908, 729.

of a baby, the autopsy on which showed biliary cirrhosis[43] and a patent bile-duct, and found a similar type of stool.

Tuberculous peritonitis in babies is primarily a disease of the lymphatic system and when the mesenteric glands become caseous they form a dam beyond which the fat cannot pass. It has been shown earlier in this paper that part of the fat is normally carried by the lymphatics to the blood stream. If this road is blocked with tuberculous tissue, it is reasonable that some of the fat should be lost from the body. I have found large amounts of fat in the stools of such babies. Hecht believes that 80 per cent. of the fat in the stool should be split, and considers that great divergence from this amount means either trouble with the bile or pancreatic juice. He reports a seven months, premature baby which was only able to split 53 per cent. of the fat, and considers this to be due to weak action of the pancreatic fat-splitting enzyme, which presumably is not completely developed. Finizio[44] explains a large amount of fat in the stool of an 11-months-old baby with mumps by probable trouble in the pancreas.

Czerny[45] believes that babies with an exudative diathesis can be harmed by fat. He finds that an increase in the amount of fat in the food will bring eruptions out on the skin. Steinitz and Weigert[46] have apparently proved the correctness of this assumption by a metabolism experiment.

There is no doubt that large amounts of fat can do a great deal of harm to most babies. Such babies come under two classes—those which have a normal digestion and are unable to digest excessive amounts of fat, and those which have diminished powers of digestion and are unable to digest normal amounts of fat. So much attention has been paid to the few babies that are unable to digest fat that we are apt to forget that most babies can digest fat within reasonable limits. L. F. Meyer[47] has recently shown in Finkelstein's clinic that when fat is increased in the food of normal healthy babies there is no loss of fat, or salts from the body. This dispels, in a very convincing way, the false impression that normal babies are unable to digest fat. John Howland of New York showed in a recent investigation (not yet published) that a baby could be fed on large quantities of fat without symptoms of indigestion and without acidosis. In my experience, it has been safe to increase the

43. Morse, J. L.: Jaundice in the New-Born, Boston Med. and Surg. Jour., Feb. 24, 1910.

44. Finizio: A Case of Fat Diarrhea Following Mumps, Pediat., September, 1909; Rev. in Jahrb. f. Kinderh., 1910, lxxi, 205.

45. Czerny: Zur Kenntnis der exudative Diathese, Part 1, Monatschr. f. Kinderh., 1906, iv, 1; ibid. Part 2, 1908, vi, 1; ibid. Part 3, 1909, vii, 1.

46. Steinitz and Weigert: Monatsch. f. Kinderh., 1910, ix, 385.

47. Meyer, L. F.: Jahrb. f. Kinderh., April, 1910, p. 379.

percentage of fat gradually up to 4 per cent. in most normal babies whose digestive powers have not previously been lowered by gross errors in feeding or by infection, and that they develop normally without any of the signs or symptoms of fat indigestion so long as their hygiene is perfect and they have no intercurrent infection.

APPENDIX

METHODS OF ESTIMATION OF FAT IN FECES

There is no such thing as a theoretically perfect method of estimating fat in the feces. The methods employed may be grouped under two heads: 1. Extraction methods which attempt to obtain all the substances soluble in ether. 2. Saponification methods, in which the higher fatty acids are set free by saponification from the various combinations in which they occur, separated as far as possible from the other products of the action of alkali used, and weighed as fatty acids.

EXTRACTION METHODS

These methods estimate all the substances soluble in ether without considering what form the fat was in. The criterion in determining the value of the particular method under consideration has been the gross yield of substance soluble in ether. The method which has been taken as a standard in recent years is that of Rosenfeld, because it gave higher yields than other methods of substances soluble in ether. This method has been criticized because the substances weighed contain nitrogen and phosphorus and a low percentage of fatty acid. I used a modification of this method[48] as follows:

The feces are weighed, thoroughly mixed with 95 per cent. alcohol and dried at 43-45 C., transferred to a desiccator, and dried to constant weight. A weighed portion of the dried feces is placed in a paper capsule and boiled in absolute alcohol for one-half hour. The capsule is then transferred to a Soxhlet tube and extracted eighteen hours with chloroform. The combined absolute alcohol and chloroform extracts are evaporated to dryness, and the residue from each extracted with petroleum ether. The petroleum ether is then filtered and the filter paper thoroughly washed with warm petroleum ether until the wash ether shows no trace of fat, by evaporation on a watch glass. The filtrate is evaporated to constant weight. This weight is recorded as representing the quantity of neutral fat and fatty acid in the weighed portion of dry stool.

The dishes used for the evaporation of the alcohol and chloroform extracts from the first extraction are washed with hot 3 per cent. hydrochloric acid alcohol. The filter paper, used for filtering the petroleum ether in the first step, is added to the capsule from which the neutral fat and fatty acid have been extracted and boiled one-half hour under a reflux condenser in 3 per cent. hydrochloric alcohol to which the HCl alcohol washings from the dishes, mentioned in the first step, are added. Next, it is boiled one-half hour with absolute alcohol; the combined capsule and filter paper are then transferred to a Soxhlet tube and extracted for eighteen hours. The hydrochloric acid absolute alcohol and chloroform extracts are evaporated separately, the residue in each is taken up in petroleum ether and the combined petroleum ether extract is filtered. The filtrate is evaporated to constant weight; this represents soaps.

The neutral fat and fatty acids (the fat first weighed) are dissolved in equal parts of absolute alcohol and sulphuric ether and the acidity determined by titrating against decinormal alcoholic sodium hydrate solution, using phenolphthalein as an indicator.

Kumagawa and Suto[49] found that the solvent which gave the largest yield of substances soluble in ether was alcohol used near its boiling point in a continu-

48. Boston Med. and Surg. Jour., Jan. 11, 1908.

49. Kumagawa and Suto: Ein neues Verfahren zur quantitativen Bestimmung des Fettes und der unverseifbaren Substanzen im tierischen Material nebst der Kritik einiger gebräuchlichen Methoden, I, Biochem. Ztschr. 1908, viii, 212.

ous extraction apparatus. This explains why the Rosenfeld method and its modifications obtain higher yields of fat than other methods. The Rosenfeld method, however, is the best one yet devised to estimate the relative proportion of neutral fat, fatty acids and soaps.

Folin and Wentworth[50] criticize this method because they have observed that prolonged chloroform extraction brings away materials with a distinct fecal odor, and they say that the best method for extraction is that which takes out the smallest amount and not that which extracts the largest amount. They have devised a method which apparently has many advantages over the Rosenfeld method. It is briefly as follows:

One gram of very finely powdered feces is weighed into a fat-free paper capsule, placed in an extraction apparatus and boiled twenty hours with an ethereal hydrochloric acid solution. The ether is then distilled off and with it goes the hydrochloric acid. A low boiling petroleum ether (Ligroin) is added and allowed to stand over night. This solution is filtered the next day into a weighed beaker and dried at a temperature of 95 C. for five hours. It is then dried and weighed as neutral fat and fatty acids. The next step is a new departure in chemistry, according to Folin and Wentworth, and is very important. The fat is dissolved in benzol, .5 per cent. alcoholic phenolphthalein added and it is heated almost to boiling. It is then immediately titrated against N/10 sodium alcoholate (made by dissolving 2.3 gm. metallic sodium in one liter absolute alcohol and standardized); 1 c.c. of this=28.4 m.gm. stearic acid. This method of titration undoubtedly has a great advantage over all that have been devised thus far.

SAPONIFICATION METHOD

Lieberman-Szekely described a method of determining the fat in the stool by first saponifying it and then splitting with acid and extracting with ether. This extract was purified with petroleum ether. This method does not estimate the fat in the stool, but all the higher non-volatile fatty acids in various combinations; and according to Kumagawa-Suto the fat may be reckoned from this by multiplying by the factor 1.046.

Kumagawa and Suto's[49] method gives the highest results of all methods and has been controlled by very accurate and painstaking experiments. It is as follows:

Two to 5 gm. of powdered feces are mixed in a beaker with 25 c.c. 5 per cent. NaOH (20NaOH in 100 c.c.) and heated two hours over a water bath. The beaker should be covered with a watch glass during this process. During the saponification the mixture is stirred now and then with a glass rod. After about ten minutes the powder dissolves and there are small flocculi left behind. After about two hours, the solution is transferred, still hot, into a hermetically closed separating funnel with a capacity of 250 c.c. The beaker is washed two or three times with about 5 c.c. warm water. Next the solution is acidified with 30 c.c. 20 per cent. H_2SO_4. After cooling well 70 to 100 c.c. ether is added and shaken well. A precipitate remains between the layers of solution. The clear water is decanted after separation. Then the brown colored ether is carefully decanted into a beaker. The funnel with the precipitate is washed twice with ether; it is then dissolved and shaken again with 30 to 50 c.c. ether and to that is added the strongly acid water of the first shaking, and it is again well shaken. The reaction is then acid and the remaining fatty acid is dissolved in the ether. These ether extracts are united, evaporated and again taken up with absolute ether, filtered through asbestos and evaporated. This extract, which contains coloring matter, fatty acid, lactic acid and other components, is heated at 50 C. first and extracted with petroleum ether. If this solution is milky it is allowed to stand one hour and then filtered through asbestos, dried at 50 C. and weighed. More detail concerning this method may be obtained by referring to Kumagawa and Suto's original article in which there is a vast amount of experimental data and criticism of other methods. In it the bibliography concerning the extraction of

50. Folin and Wentworth: Determination of Fat and Fatty Acid, Jour. Biol. Chem., June, 1910.

fat from the animal tissue is very complete. These findings have been substantiated by Inaba.[51]

Bahrdt, Edelstein, Langstein and Welde[52] have used a new method for the quantitative estimation of the free volatile fatty acids in the feces. This method is based on a method by W. Steinkepf which used vacuum distillation and steam for extraction. The method in brief is as follows:

A weighed amount of fresh feces was distilled in a temperature of 60 C. for two hours, with steam drawn through on the one side by a vacuum on the other. The distillate is titrated against N/10 sodium hydrate, with phenolphthalein as an indicator. The amount of acid present is estimated in terms of decinormal acid. The temperature of the water bath during the whole distillation should be 60 C. Generally the distillation goes well if there are 600 to 900 c.c. distillate in one hour. The original article should be consulted for detail of the method and the apparatus necessary.

This brief description of the newer methods of fat and fatty acid extraction has been added so that those who have a desire to commence metabolism work on babies will be able to choose for themselves and go back to the original sources. I feel that the last word has not been said, and that it is necessary to extract all feces, both by the Kumagawa and Suto method, and by some modification of the Rosenfeld method. The method offered by Folin and Wentworth is still in the experimental stage and the writers are "now working to perfect it."

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51. Inaba: Biochem. Ztschr., 1908, viii, 352.

52. Bahrdt, Edelstein, Langstein and Welde: Untersuchung über die Pathogenese der Verdauungsstörungen im Säuglingsalter, Ztschr. f. Kinderh., 1910, i, No. 2, 139.

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